# SCANNER-ILLUMINATED LCOS PROJECTOR FOR HEAD MOUNTED DISPLAY

## STATEMENT OF RELATED APPLICATIONS

This application claims benefit and priority to U.S. Provisional Application Ser. No. 62/483,250 filed Apr. 7, 2017, entitled "Scanner-Illuminated LCOS Projector for Head Mounted Display" which is incorporated herein by reference in its entirety.

## BACKGROUND

Mixed-reality computing devices, such as head mounted display (HMD) systems and handheld mobile devices (e.g. smart phones, tablet computers, etc.), may be configured to display information to a user about virtual and/or real objects in a field of view of the user and/or a field of view of a camera of the device. For example, an HMD device may be configured to display, using a see-through display system, virtual environments with real-world objects mixed in, or real-world environments with virtual objects mixed in. Similarly, a mobile device may display such information using a camera viewfinder window.

## SUMMARY

A small form factor light engine comprises a liquid crystal on silicon (LCOS) panel that is operated as a pico projector in combination with illumination and imaging optics to couple high-resolution virtual images into a waveguide-based exit pupil expander (EPE) that provides an expanded exit pupil in a near-eye display system. In an illustrative example, the illumination optics comprise a laser that produces illumination light that is reflected by a MEMS (microelectromechanical system) scanner, using raster scanning, to post-scan optics including a microlens array (MLA) and one or more collimating or magnifying lenses before impinging on the LCOS panel. The LCOS panel operates in reflection in combination with imaging optics, including one or more of beam-steering mirror and beam splitter, to couple virtual image light from the LCOS panel into the EPE.

Using the LCOS panel as the virtual image source enables projection of high resolution virtual images with a large field of view (FOV) (e.g., greater than 60 degrees) into the EPE. The combination of the MEMS scanner and laser efficiently provides illumination to the LCOS panel while consuming less power than conventional illumination systems such flood illumination. The post-scan optics enable an increase in exit pupil size (e.g., greater than 2 mm) which can broaden the light cone incident on a given pixel in the LCOS panel. The exit pupil of the projector is coupled into the EPE, which may replicate or further expand the pupil in either one or two directions of the FOV. The increased size of the projector pupil can facilitate reduction in artifacts from pupil replication.

By decoupling the imaging and illuminations functions, the MEMS scanner design can be optimized for illumination since it does not need to handle light from the image source. Therefore, scanner resolution and FOV are not design drivers. In addition, the MEMS scanner may be configured to modulate per-color intensity in implementations, for example, in which an RGB (red, green, blue) color model is utilized. Such modulation may be advantageously employed to improve the low-frequency non-uniformity that can arise in waveguide-based displays and be manifested as dark areas within one or more of the color channels. The MEMS scanner modulation reduces local non-uniformities in the display while preserving the bit-depth of the LCOS panel. As a result, contrast ratio and overall brightness of the display typically are increased.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure.



## DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a block diagram of an illustrative near-eye display system;

FIG. **2** shows propagation of light in a waveguide by total internal reflection (TIR);

FIG. **3** shows a view of an illustrative exit pupil expander;

FIG. **4** shows a view of an illustrative exit pupil expander in which the exit pupil is expanded along two directions of the field of view (FOV);

FIG. **5** shows an illustrative input to an exit pupil expander in which the FOV is described by angles in horizontal, vertical, or diagonal orientations;

FIG. **6** shows a pictorial front view of a sealed visor that may be used as a component of a head mounted display (HMD) device;

FIG. **7** shows a partially disassembled view of the sealed visor;

FIG. **8** shows an illustrative arrangement of diffractive optical elements (DOEs) configured for in-coupling, exit pupil expansion in two directions, and out-coupling;

FIG. **9** shows an illustrative projector arrangement used for imaging optics in a light engine employing a direct eyepiece;

FIG. **10** shows an illustrative projector arrangement used for imaging optics in a light engine employing a birdbath mirror;

FIG. **11** shows an illustrative example of illumination optics in a light engine using a Koehler illumination arrangement;

FIG. **12** shows an illustrative example of illumination optics in a light engine using a critical illumination arrangement;

FIG. **13** shows an illustrative example of illumination optics in a light engine using a scan-beam-based illumination arrangement;

FIG. **14** shows a profile of a portion of an illustrative diffraction grating that has straight gratings;

FIG. **15** shows a profile of a portion of an illustrative diffraction grating that has asymmetric or slanted gratings;

FIGS. **16-19** show various illustrative two-dimensional diffraction gratings;

FIG. **20** is a pictorial view of an illustrative example of a virtual reality or augmented reality HMD device that may use a scanner-illuminated LCOS projector;

FIG. **21** shows a block diagram of an illustrative example of a virtual reality or augmented reality HMD device that may use a scanner-illuminated LCOS projector; and

FIG. **22** shows a block diagram of an illustrative electronic device that incorporates an augmented reality display system that may use a scanner-illuminated LCOS projector.